Automated Sleep-Wake Detection in Neonates from Cerebral Function Monitor Signals

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Abstract

Amplitude-integrated electroencephalography (aEEG) is a technique that compresses the time scale of conventional electroencephalography (EEG) and is displayed on Cerebral Function Monitors (CFM). This is advantageous for interpreting global cerebral activity in neonates, including sleep patterns. Sleep-wake cycling in infants is often used as an indicator of the patient's neurological development and response to brain injury. The development of a robust, accurate and reliable algorithm for the incorporation into the Artemis Platform, to detect sleep-wake cycling in newborn infants greater than 29 weeks gestational age should provide valuable information for meaningful clinical decision support for physicians caring for critically ill neonates.

I. INTRODUCTION

The development of sleep-wake cycling which first appears at 29 weeks gestational age and is fully developed by 44 weeks is a clinical indicator of current neurological status and long-term outcome [1][2]. Through the analysis of amplitude-integrated electroencephalogram (aEEG), this can be used to visualize sleep-wake cycling in infants. When a broader or expanded aEEG bandwidth is seen, this represents discontinuous background activity during quiet sleep, and a narrow, thinner bandwidth corresponds to a lower voltage, more continuous activity during waking stage and active sleep [1][3][4].

The development of computer programs has led to an increased ability for real-time analysis, data mining and storage of patient data streams to help contribute to the clinical decision making process. An exemplary platform is the Artemis Platform developed at the University of Ontario Institute of Technology (UOIT). The Artemis Platform has been developed to provide a flexible platform for real-time online health analytics and offline analysis of patients’ data streams with the capability to store raw, physiological data together with derived analytics [5]. Through the design of algorithms within the Artemis framework, the aim is to detect medically significant conditions that precede the onset of medical complications with a future goal to make Artemis a robust clinical decision support tool that provides insight into the meaning of multiple streams of Big Data, normally too large to assess using traditional methods [5].

Many algorithms have been developed for the automated detection and analysis of seizures and other patterns displayed by EEG and aEEG, however, none have focused on the automated detection of changes in normal sleep-wake cycling patterns in infants [6]. Currently the best methods for automated detection of patterns displayed by aEEG are based on computing a running autocorrelation function, rhythmic discharge detection, modeling or complexity analysis, and wave-sequence analysis [7]. Others have been performed based on the withdrawal of features using entropy, wavelets, frequency content, and then training a classifier on these features to accurately classify the EEG [8]. The goal of this research is to address the question of whether or not an accurate, automated real-time algorithm can be developed for the Artemis framework to detect variance of sleep-wake cycling from an aEEG signal.

II. METHODOLOGY

To construct the original algorithm, a single patient data set with corresponding screen shots of the patients CFM data was used. Annotations indicating when the patient was asleep and awake throughout the 24 hours of each patient’s aEEG tracing has been performed by a neonatologist, neurologist and respiratory therapist from The Hospital for Sick Children. From this stage, 15 patient data sets with associated screen shots and expert annotations were selected as the training set for further algorithm refinement. 15 more patient
data sets with corresponding annotations will then be used as the study population.

CFM data are routinely interpreted by eye using established clinical guidelines [9]. This interpretation uses as a basis the upper and lower thresholds of the CFM traces.

To automate this, a boundary detection algorithm will be employed which searches for the local minima and maxima over a sliding window of the data. In this case the window size will be set to 3000 samples or 30 seconds. These local minima and maxima are then interpolated to produce a new waveform of the same resolution as the original CFM waveform, but showing instead the boundaries that are detected by the human eye.

Upper and lower thresholds are then used to determine the width of the CFM trace by filtering using a fourth-order, low pass Butterworth filter to smooth out the boundaries. The difference between these bands is then used with a threshold detector based on the upper and lower boundaries of the trace to determine if the neonate is awake or asleep. An overview of the sleep-wake classification process is shown in Figure 1. The output of the algorithm will result in a binary function that matches the CFM trace, indicating when the patient is asleep by a high value (1) and awake with a low value (0).

![Figure 1- Overview of sleep-wake classification process](image)

**III. CONCLUSION**

The detection method will mimic the visual analysis performed by physicians in the interpretation of these signals by detecting the upper and lower bounds of the aEEG signals over periods of time and measuring the distance between them. This method was able to detect all sleep-wake changes in state with fair accuracy in the onset times.

Sleep-wake cycling in infants carries great significance as it is often used as a measurement of the patient’s neurological development. The absence or delayed development of sleep-wake cycling patterns on aEEG can be the result of neonatal hypoxic-ischemic encephalopathy, infection, motor and cognitive impairment, asphyxia, or unilateral brain injury [2]. This work has potential significance if the algorithm can determine when sleep-wake cycling states are occurring at a faster and more accurate rate than manual interpretation which can aid in the timing of medical intervention.

**IV. REFERENCES**